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FIELD OBSERVATIONS

UPON THE

TOLERANCE OF THE SUGAR BEET FOR ALKALI.

By G. W. SHAW.

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FIELD OBSERVATIONS UPON TOLERANCE OF THE SUGAR BEET FOR ALKALI.

By G. W. SHAW.

While acting as agricultural expert for a company interested in the beet industry in Colorado, the attention of the writer was frequently drawn to the effect of the soluble-salt constituents of the soil (alkali) upon the sugar beet. On account of the fact that the general conditions which obtained in the irrigated regions are especially favorable to the production of high-grade beets, and since in such regions there are usually to be found many acres of land upon which these soluble salts appear in greater or less concentration and frequently have killed the normal vegetation, and especially because of much apparent contradiction in the action of these lands toward the sugar-beet crop, the writer became interested in attempting to determine the limits of tolerance of the sugar beet toward alkali, and it is as a contribution to this work that this bulletin is prepared, reviewing certain work which was conducted by the writer in 1900 at Grand Junction, Colorado, and extended during the summer of 1904 at Oxnard, California.

PREVIOUS WORK IN CALIFORNIA.

Certain investigators, notably Drs. Hilgard and Loughridge of this Station, and Professors Buffum and Slosson of the Wyoming Station, had already conducted some interesting and suggestive work upon the relation of alkali to sugar beets. Dr. Loughridge,* in discussing the toleration of alkali by sugar beets grown in three different localities, shows it to be:

	Sulfates.	Carbonates.	Chlorids.	Nitrates.	Total.
No. 1	8,920	3,360	3,280	1,440	17,000
No. 2	7,160	3,040	1,520	560	12,280
No. 3	2,360	3,360	3,280	320	9,320

From this and other data he concludes that the limit of tolerance for sugar beets, so far as he has observed, is as follows.

For sulfates	over 7,000 lbs. per acre†
For sodium chlorid	" 1,500 " " "
For sodium carbonate	" 3,000 " " "
For nitrates	" 2,600 " " "

He considers chlorids and nitrates even more injurious than carbonates and sulfates. He says:‡ "The data and observations recorded * * * prove beyond question that sugar beets of good and even high

* Loughridge, R. H.: California Experiment Station Report, 1895–96, p. 49.

† To depth of three feet in each case.

‡ Hilgard and Loughridge: California Experiment Station Report, 1894–95, p. 90.

grade, both as to sugar and purity, may be grown on land containing as much as 12,000 pounds of alkali salts per acre to the depth of three feet; provided that the percentage of common salt does not exceed an average of 0.04 per cent, or 1,600 pounds per acre." The above figures are "not final, and good sugar beets might be grown with a higher per cent of any one of the salts, all other conditions being favorable." In a later report* it is stated that on soil containing from 7,000 to 12,000 pounds of alkali (in three feet), chiefly glauber salt, excellent sugar beets were grown at the Southern California substation, but at from 18,000 to 20,000 pounds they failed to produce a crop. Beets grown on the former soil averaged 14.1 per cent of sugar; purity, 80 per cent.

OBSERVATIONS IN COLORADO.

It is regretted that the circumstances in Colorado did not permit a more thorough examination of the under soil, for in but few cases was it possible to extend the work to a greater depth than the top foot—the writer having removed to California before the completion of the work contemplated. However, the limited number of analyses taken, together with field observations and the experience of certain farmers in the application of water, seems to indicate that in the virgin soil the heavy per cent of alkali lies above the fourth foot, and that the shallow irrigation practiced has brought the excessive amounts now in the surface foot from that depth. This evil effect of shallow irrigation has been augmented by underground seepage from the canals in the localities which are inclined to sandy loams, by an upward leaching of the soil.

The following soluble-salt determinations made upon soils producing either good or fair crops of beets indicate the condition of the top foot in such fields:

TABLE I.—*Soluble Salts in Colorado Soil Producing Fair Crops.*

No	Locality.	Per Cent.				Pounds per Acre-foot.			
		Chlorids.	Carbonates.	Sulfates.	Total.	Chlorids.	Carbonates.	Sulfates.	Total.
7	Sec. 13, T. 1 S., R. 1 E.	.023	trace	.139	.162	920	trace	5,560	6,480
10	Sec. 19, T. 1 S., R. 1 E.	.070	trace	.114	.184	2,800	trace	4,560	7,360
15	Sec. 9, T. 1 N., R. 1 E.	.028	.007	.032	.067	1,120	280	1,280	2,680
†20	Sec. 5, T. 1 N., R. 1 E.	.036	.014	.172	.222	1,440	560	6,880	8,880
19	Sec. 5, T. 1 N., R. 1 E.	.046	.005	.113	.164	1,840	200	4,520	6,560
22	Sec. 16, T. 1 S., R. 1 E.	.036	.007	.159	.202	1,440	280	6,360	8,080
23	Sec. 15, T. 1 S., R. 1 E.	.019	.003	.042	.064	760	120	1,680	2,560
35	Sec. 11, T. 1 N., R. 2 W.	.034	.004	.006	.044	1,360	160	240	1,760
	Average	.036	.004	.087	.127	1,440	160	3,480	5,080

* Hilgard, E. W.: California Experiment Station Report, 1897–98, pp. 129, 142.

† An uncultivated soil. Not included in the average.

TABLE II.—*Soluble Salts in Colorado Soils Producing Poor Crops of Beets.*

No.	Locality.	Per Cent.				Pounds per Acre-foot.				Remarks.
		Chlorids	Carbonates	Sulfates	Total	Chlorids	Carbonates	Sulfates	Total	
1	Sec. 4, T. 1 N., R. 1 E.	.807	.008	.482	1.297	32,280	320	19,280	51,880	Beets and alfalfa killed.
2	Sec. 1, T. 1 S., R. 1 E.	.081	.021	.572	.674	3,240	840	22,880	26,960	Beets, corn, and tomatoes failed.
4	Sec. 5, T. 1 S., R. 1 E.	.324	.246	.727	1.297	12,960	9,840	28,880	51,880	Beets failed.
5	Sec. 24, T. 1 N., R. 2 W.	.464	.122	.014	.600	18,560	4,880	560	24,000	Beets poor.
8	Sec. 13, T. 1 S., R. 1 E.	.418	.008	.780	1.206	16,720	320	31,200	48,240	Beets failed in this spot.
9	Sec. 32, T. 1 N., R. 1 W.	.021	trace	.235	.256	840	trace	9,400	10,240	Beets poor.
11	Sec. 17, T. 1 S., R. 1 E.	.139	.093	.527	.759	5,560	3,720	21,080	30,360	Beets very poor in this spot.
13	Sec. 8, T. 1 N., R. 2 W.	.232	trace	.114	.346	9,280	trace	4,560	13,840	Beets poor.
16	Sec. 9, T. 1 N., R. 1 E.	.036	.007	.208	.251	1,440	280	8,320	10,040	Beets poor.
17	Sec. 17, T. 1 S., R. 1 E.	.153	.003	.090	.246	6,120	120	3,600	9,840	Beets poor.
18	Sec. 17, T. 1 S., R. 1 E.	.176	.005	.093	.274	7,040	200	3,720	10,960	Beets poor.
21	Sec. 32, T. 1 N., R. 2 W.	.158	.005	.081	.244	6,320	200	3,240	9,760	Beets poor.
29	Sec. 8, T. 1 N., R. 2 W.	.069	.081	.302	.452	2,760	3,240	12,080	18,080	Beets poor.
32	Sec. 8, T. 1 N., R. 2 W.	.697	.016	2.129	2.842	27,880	640	85,160	113,680	Two seedings of beets failed.
34	Sec. 11, T. 1 N., R. 2 W.	.255	.008	.319	.582	10,200	320	12,760	23,280	Beets failed in this spot.
30	Sec. 24, T. 1 S., R. 1 E.	.962	.003	.361	1.326	38,480	120	14,440	53,040	Beets failed.
	Average of above	.312	.039	.440	.791	12,480	1,460	17,600	31,640	
3	Roadside	.344	.081	1.292	1.717	13,760	3,240	51,640	68,680	No weeds.
25	Sec. 11, T. 1 N., R. 2 W.	.371	.004	4.825	5.200	14,840	160	193,000	208,000	Orchard and alfalfa killed, barren.
26	Sec. 11, T. 1 N., R. 2 W.	.209	.023	1.324	1.556	8,360	920	52,960	62,240	Apple trees killed, since drained.
27	Sec. 11, T. 1 N., R. 2 W., 2d ft.	.092	.014	.974	1.080	3,680	560	38,960	43,200	Apple trees killed, since drained.
28	Sec. 11, T. 1 N., R. 2 W.	.116	.101	.190	.407	4,640	4,040	7,600	16,280	Apple trees killed, since drained.
36	Sec. 9, T. 1 N., R. 2 W.	.603	.008	1.257	1.868	24,120	320	50,280	74,720	Peach, pear, and apple trees killed.
37	Sec. 8, T. 1 N., R. 2 W.	.464	.016	1.334	1.814	18,560	640	53,360	72,560	Fruit trees affected.
38	Sec. 8, T. 1 N., R. 2 W.	.742	.010	1.348	2.100	29,680	400	53,920	84,000	Alfalfa dying.
39	Sec. 9, T. 1 N., R. 2 W.	.429	.005	3.138	3.572	17,160	200	125,520	142,880	Orchard and alfalfa killed.

While the yield in these fields is not high when considered independently, yet, as compared with the remainder of the section and in connection with the seasonal yield of the region, it was *above the average*, being 8.45 tons per acre, and ranging from 7.76 tons to 20.98 tons, with an average sugar-content of 16.03 per cent and purity of 81.8 per cent.

The indication here is that while the soluble-salt content of these soils is high, yet fair and even good beets can be produced even when the total alkali-content reaches as high as 5,000 pounds *in the top foot*, and may perhaps even reach 7,000 pounds, other conditions being favorable.

In other localities, however, the conditions were quite different, as will be seen in Table II, showing results from fields failing to produce crops, although the conditions of cultivation, etc., were as good as in the former cases.

Comparing, now, the figures in Table II with the limits indicated above, estimating that the Grand Junction soil carries three fourths of the alkali in the top foot, we find that on the ground where beets failed, fifteen out of sixteen samples carried in the top foot much more chlorid than the total amount named above for three feet, and that the average was ten times the figure given above. In the single case where the chlorids were low the sulfates alone surpassed the 9,000-pound limit for the top foot.

A just consideration of these facts leaves little doubt as to the primary causes of many of the failures with the beet crop on these soils, although it is but just to say that large areas in the locality are well adapted to the beet, and that by a proper discrimination as to soils these difficulties may be obviated.

OBSERVATIONS AT OXNARD.

Opportunity offered during the season of 1904 to extend observations along the same line, at Oxnard, California. It may be said at this point that the general conditions in this locality for the production of sugar beets, both as to quality and quantity, are exceptionally good, and the conditions here presented are for special fields and are not presented as representing widespread conditions.

After a preliminary examination, certain fields were selected for study, mainly because the appearance of the beets, the general condition of their crop, and the appearance of the soil, so closely resembled those observed at Grand Junction, Colorado.

Appearance of Alkalied Beets.—As to the crop in the affected fields, the condition which would first attract attention was the "patchy" appearance of these fields. This was due to a very uneven stand, and to a considerable irregularity in the size of the plants in the various

parts of the fields. Almost equally striking was the prevalence of chlorosis of the older leaves and a sprangling tap-root, in some cases entire fields being thus affected, but more often only portions of certain fields.

The beets of these fields had a distinctly different appearance from the so-called "blighted" beets, and were not characterized by such an abnormal development of side roots as usually accompanies the former conditions. Nor was there the characteristic darkening of the outer layer of cells of the crown and basal portion of the petioles.

The reader will better perceive the difference in the appearance of a typical "alkalied" beet and one affected with the so-called "blight," by contrasting the following illustrations:

Fig. 1. Beets stunted by alkali.

Fig. 2. Beet affected by "blight."

This may be due to several causes: (*a*) The alkali may retard, or even prevent the germination of the seed; (*b*) it may destroy the plants after germination, either on account of its concentration as a whole, or of some one of its ingredients.

Difficulty in Securing a Good Stand in Alkali Soil.—Often the greatest difficulty is experienced, in localities subject to alkali, in securing a good stand of beet plants. This usually is more true of clay than of sandy soils. An examination of ground destitute of plants will nearly always reveal either the presence of an alkali-content on the surface of such spots, or the peculiar fine dust mulch so common in such regions. Even though the beets are caused to germinate by irrigation in such cases, the stand is invariably uneven.

In such cases it is undoubtedly true that the density of the soil solu-

tion has been too great, thus destroying the vitality of the seed, or, in the case of germination, the plants died very shortly from a constantly increasing density of the soil solution. This would soon reach such a degree of density as to so nearly equal that of the plant that passage of water from the soil into the plant was checked, and starvation from a lack of water results.

In an investigation as to the strength of the soil solution in the Colorado analyses, the writer found, for the top foot of the soil, the following results:

Percentage in Soil Water.

Depth.	Sulfates.	Carbonates (as Sodium Carbonate).	Chlorids (as Sodium Chlorid).	Total Alkali.
For 20% water	1.86	.14	.97	2.97
For 10% water	3.66	.27	1.93	5.86

The calculation was made for 10 per cent and 20 per cent because of an investigation of the amount of water present in a field with heavy soil and made at the time when the plants were growing and when they were not. Two days after irrigation there was found to be from 18 to 20 per cent of water in a heavy adobe soil on the side of the plant next to the water furrow.

The soil in the same field, when it had not been irrigated for several days, contained but 8 to 12 per cent. In the latter case the plants had not ceased growing, but were suffering from lack of water. This concentration of solution, beyond question, had a bearing upon the retardation or prevention of germination.

EXPERIMENTS IN WYOMING.

At the Wyoming Experiment Station, Prof. E. E. Slosson* experimented with solutions of magnesium and sodium sulfate, sodium chlorid, and sodium carbonate, using seeds of corn, sunflower, peas, wheat, rye, buckwheat, alfalfa, rape, and scirpus. The effect of sodium carbonate was to corrode , disintegrate, and destroy the seed, if more than small amounts were used; as a result, only the neutral salts were used throughout the experimentation, since sodium carbonate entirely prevents germination. In summing up the results of a long series of experiments, he concludes that in all cases the presence of salts in solution hinders the absorption of water in a ratio increasing with the osmotic pressure of the solution. Dilute solutions of alkali retard germination, stronger solutions prevent it entirely. He used solutions

* Slosson, E. E.: Alkali Studies IV, pp. 1-29, July, 1899: Wyoming Agricultural Experiment Station Report for 1899.

varying from 0 to 9 per cent. The retarding effect was greatest when sodium carbonate or sodium chlorid was used. There was a wide difference shown in the deleterious effects of alkali upon the seeds of different species.

Prof. B. C. Buffum conducted a series of experiments quite like those by Professor Slosson. His conclusions are similar, and are as follows:

(1) "The presence of very small amounts of sodium sulfate, sodium chlorid, magnesium sulfate, or sodium carbonate undoubtedly has a beneficial effect on the germination of seeds and the growth of plants.

(2) "Of the salts most abundant in the alkali of the arid regions, those that have the greatest detrimental effects on germination, in order, are: sodium carbonate, sodium chlorid, sodium sulfate, and magnesium sulfate.

(3) "The retarding effect of a salt solution on the germination of seeds is in direct proportion to its osmotic pressure, except where other factors enter in, such as the caustic effect of sodium carbonate, or where solutions are very dilute."*

The presence of over one per cent of sodium carbonate, and over nine per cent of sodium chlorid effectually prevented the germination of wheat and rye seeds. In a still later joint report by Messrs. Buffum and Slosson† are given the results of experiments conducted with the growth of wheat and alfalfa in sand containing, in addition to a nutrient solution, amounts of sodium and potassium chlorids and sulfates of known osmotic pressure. The greatest osmotic pressure used was 7.1 atmospheres—about equal to that of a sodium chlorid solution of one per cent. This not only retarded the germination of the seeds, but checked the development of the plants after germination, producing stunted plants of minimum size as compared with the check plants grown in a nutrient solution.

Since the sugar-beet seeds in the fields at Grand Junction must have been subjected at times to soil solutions very much more dense than those used by Professors Slosson and Buffum, what they found to have taken place in pots used in experimentation must have occurred to a greater degree in the field. The per cent of sodium carbonate in some fields was sufficient during periods of minimum moisture to injure those plants fortunate enough to get through when the soil contained its maximum moisture. The average of 16 to 31 per cent of soluble salts in the soil solution, even of sulfates, is sufficient to greatly retard germination, if not to entirely prevent it. The sodium chlorid, on account of its higher osmotic pressure, has a greater effect than the sulfates.

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* Buffum, B. C.: Alkali Studies III: Wyoming Agricultural Station Report for 1899.

† Buffum, B. C., and Slosson, E. E.: Alkali Studies V: Wyoming Agricultural Experiment Station Report for 1900.

The osmotic pressure exerted by the salts mentioned are estimated by Professor Slosson as follows:

Salt.	Per Cent.	Pressures, in Atmospheres.
Sodium chlorid	1	7.4
Sodium carbonate	1	4.3
Sodium sulfate	1	3.9
Magnesium sulfate	1	2.8
Sugar	1	0.7

OBSERVATIONS AT OXNARD, CALIFORNIA.

At Oxnard this unevenness of stand was marked in many fields, typical cases being seen in the illustrations referring to fields IX, XI and XII.

FIG. 3. Field IX, showing both good and poor beets.

The conditions in these fields were especially favorable for observations upon the tolerance of the sugar beet for alkali.

FIELD IX, OXNARD.

Field IX consisted of 33 acres, all planted to beets. The previous crops grown on this land had been—in 1902, hay, and in 1903, beets, which yielded 9 tons per acre, and in this portion of the field the estimated tonnage was 3 to 4 tons only. The field was exceedingly spotted in appearance, not only on account of the uneven bearing spots, which occurred in larger or smaller places all over the field, but also on account of the apparently uneven ripening of the beets. Wherever the beet leaves still appeared green, examination showed the soil to be

moist, even to the top of the ground; but where the beets appeared ripe the ground was dry and hard. The field was winter plowed to a depth of 12 inches, and seeded on March 5th in rows 18 inches apart; thinned April 16th, and harvest began August 22d. On the north and east of the field are irrigation ditches, built in 1902. While previous to that time alkali was known to exist in the locality, yet it did not show in excess until after the ditches had been constructed, which suggests the possibility of seepage from that source, although that was not positively established.

Alkali shows generally over the field, appearing in apparently larger

FIG. 4. Field IX, showing a spot of beets growing in strong alkali.

quantities in the spots where no beets were growing. One of the bare spots (see Fig. 4) surrounded an island of slightly higher ground on which were growing beets of poor form, showing the short, stubby and branching characteristics of strongly alkali soils generally. This beet island, surrounded by the perfectly bare ground on which there was an efflorescence of alkali, is well shown in Fig. 4. By cross-sectioning the field at this point, both as to soil samples and beets, we were able to pass successively through fair beets, poor beets, no beets, and to also reverse the order on the other side of the spot of beets. This, as well as the general shape of the alkali spots, is shown in Fig. 5, the location of good and poor beets, and the point at which the soil samples were taken.

Analyses showing the distribution of the soluble salts are here presented:

TABLE III.—*Soluble Salts in Field IX, Oxnard.*

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
No. IX—9.								
First foot	.2416	none	.0552	.2968	9,680	none	2,200	11,880
Second foot	.4328	none	.1104	.5432	17,320	none	4,400	21,720
Average and total	.3372	none	.0828	.4200	27,000	none	6,600	33,600
No. IX—10.								
First foot	.5277	none	.2227	.7504	21,108	none	8,908	30,016
Second foot	.3154	none	.1574	.4728	12,600	none	6,280	18,880
Average and total	.4215	none	.1901	.6116	33,708	none	15,188	48,896
No. IX—11.								
First foot	.4814	none	.1778	.6592	19,240	none	7,120	26,360
Second foot	.4213	none	.2227	.6440	16,840	none	8,920	25,760
Average and total	.4513	none	.2002	.6515	36,080	none	16,040	52,120
No. IX—12.								
First foot	.2532	none	.1196	.3728	10,128	none	4,784	14,912
Second foot	.4672	none	.0288	.4960	18,680	none	1,160	19,840
Average and total	.3602	none	.0712	.4344	28,808	none	5,944	34,752
No. IX—13.								
First foot	.1789	.010	.1211	.3100	7,160	400	4,840	12,400
Second foot	.2715	.010	.1957	.4772	10,880	400	7,840	19,120
Average and total	.2252	.010	.1584	.3936	18,040	800	12,680	31,520
No. IX—14.								
First foot	.1891	.0067	.0562	.2520	7,560	280	2,240	10,080
Second foot	.2257	.0067	.0652	.2976	9,040	280	2,600	11,920
Average and total	.2074	.0067	.0607	.2748	16,600	560	4,840	22,000
No. IX—15.								
First foot	.0825	.0033	.0562	.1420	3,320	120	2,240	5,680
Second foot	.1284	.0050	.0746	.2080	5,120	200	3,000	8,320
Average and total	.1054	.0041	.0654	.1699	8,440	320	5,240	14,000

Discussion.—In Fig. 7, showing the beets from the respective points of sampling, may be seen the characteristic appearance of "alkalied beets." In position 9 the beets in most cases were fair in size, yet now and then would be shown the "scraggly" tendency of beets growing in strong alkali soils, which in positions 10 and 14 is shown to the greatest degree.

In position 15 the beets were apparently about the same as those at 9, which is also shown in the illustration. At 12 the beets were better than at either 10 or 14, but distinctly poorer than at 9 and 15. It will be noted that the beets at 12 presented more fully the alkali character-

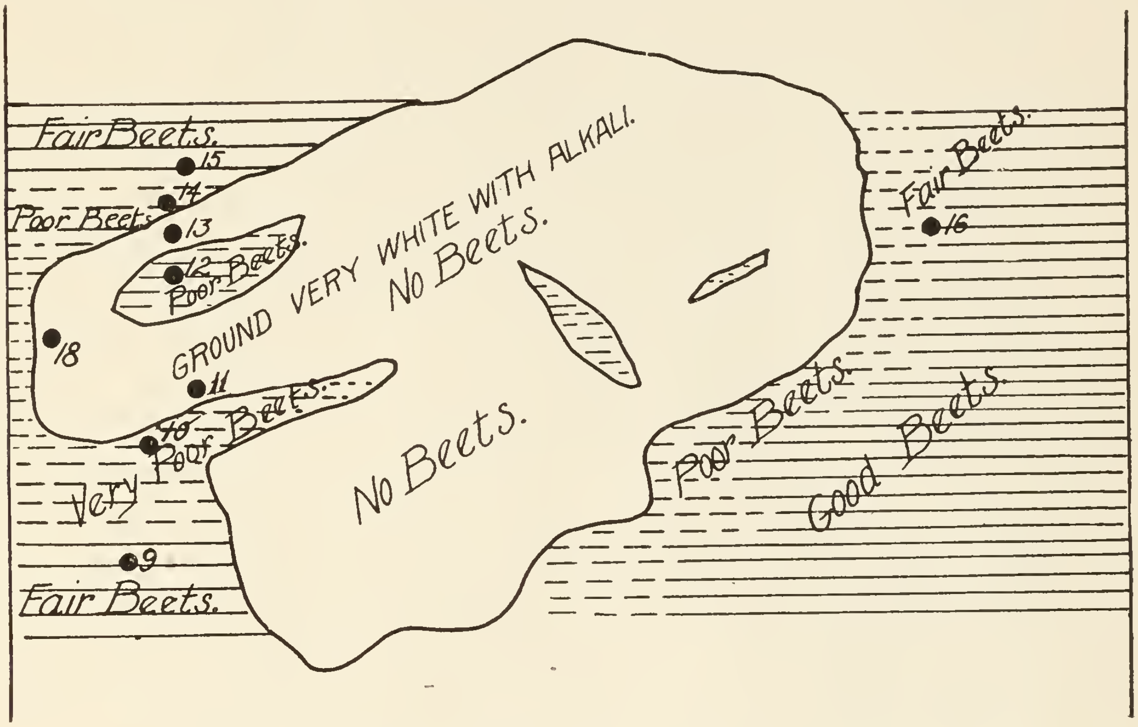

FIG. 5. Locations in Field IX where samples were taken.

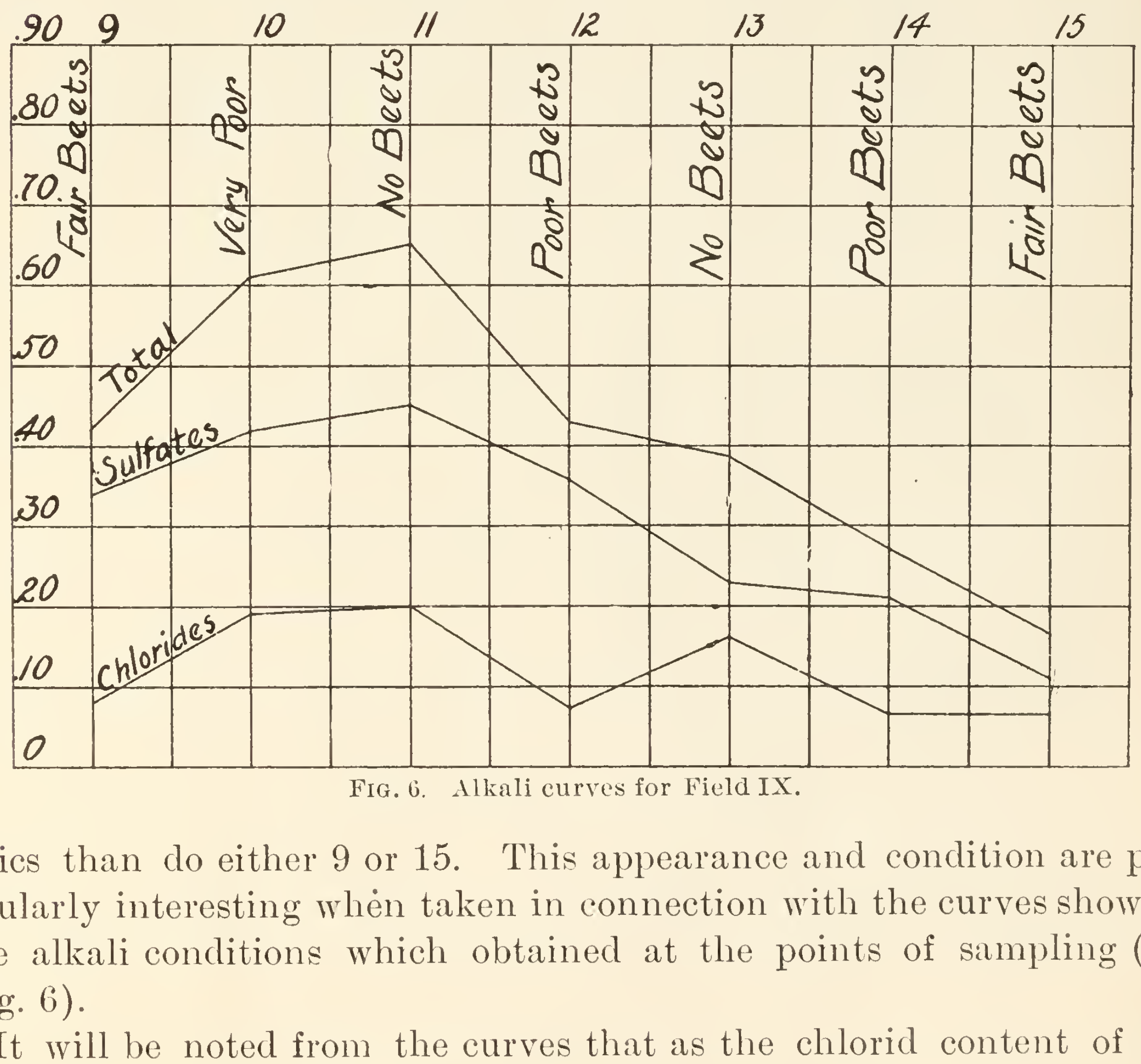

FIG. 6. Alkali curves for Field IX.

istics than do either 9 or 15. This appearance and condition are particularly interesting when taken in connection with the curves showing the alkali conditions which obtained at the points of sampling (see Fig. 6).

It will be noted from the curves that as the chlorid content of the

Fig. 7. Beets growing on the stations indicated in Fig. 6.

soil approaches .20 per cent, the beets invariably become either very much stunted in size or have been entirely destroyed from the effects of the alkali. This is especially noticed at points 10, 11, and 13, while at 12 the beets become measurably better in size, but on account of their poor form must still be classed as poor beets. Here also the chlorid content of the soil has decidedly decreased. This is also true of station 14. If we are to draw any lesson from the data here presented it would be the comparatively limited effect which the sulfates have upon the beets, and the great sensitiveness of the beet to the soluble chlorids.

These results are verified by results secured by sampling at right angles to the former cross-section and including samples 18, 12, 16, and 19. The results of which analyses show the following percentage:

Station	18.	12.	16.	19.
Condition of beets	No beets.	Poor beets.	Fair beets.	Good beets.
Sulfates	.4063	.3602	.2010	.2629
Carbonates	.0092	0000	.0044	.0101
Chlorids	.1957	.0742	.0746	.0419
Total	.6112	.4344	.2800	.3149

While the time at which the work here reported was necessarily done rendered it generally impossible to secure extended data as to the sugar-content on the several tracts, it may be said that the beets on plat IX ranged from 17 to 22 per cent sugar in the beet.

FIELD XI, OXNARD.

In Field XI the conditions were much the same as in the former case, although, owing to some subirrigation, the beets, wherever growing, were of much better size. The field had been in beets for the two years preceding and had produced good crops each year. This field lies alongside the waste ditch from the factory, and is somewhat lower than the ditch, which fact has apparently affected the field by

an upward leaching of the soil, bringing much alkali to the top. While there were 19 acres of beets originally planted in this field, but 5 acres were actually harvested, the beets carrying a sugar-content of 14.7 per

FIG. 8. General view of Field XI.

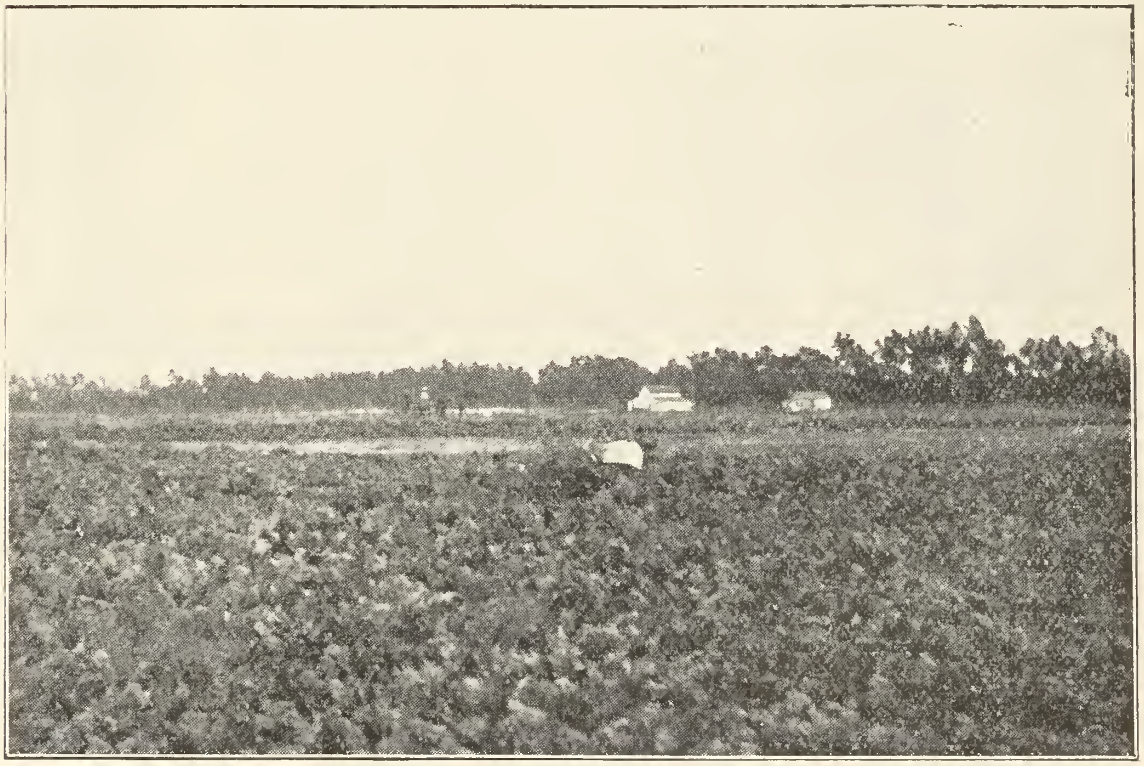

FIG. 9. Field XI, looking in opposite direction.

cent, and a purity of 78.1. In taking the soil samples water was found at points 1 and 2 at a depth of about 12 inches, while at point 1 the soil auger could be easily pressed to a depth of 8 feet, on account of the large amount of water in the soil.

The illustrations on page 15 show the appearance of Field XI at the time of sampling, Fig. 8 looking away from the waste ditch from point 6 in the line drawing (Fig. 10), while Fig. 9 reverses the view.

Fig. 10 indicates the distribution of the beets in the field, showing the stations at which the soil and beet samples were selected, and in the tables herewith presented are stated the alkali determinations for the several indicated stations.

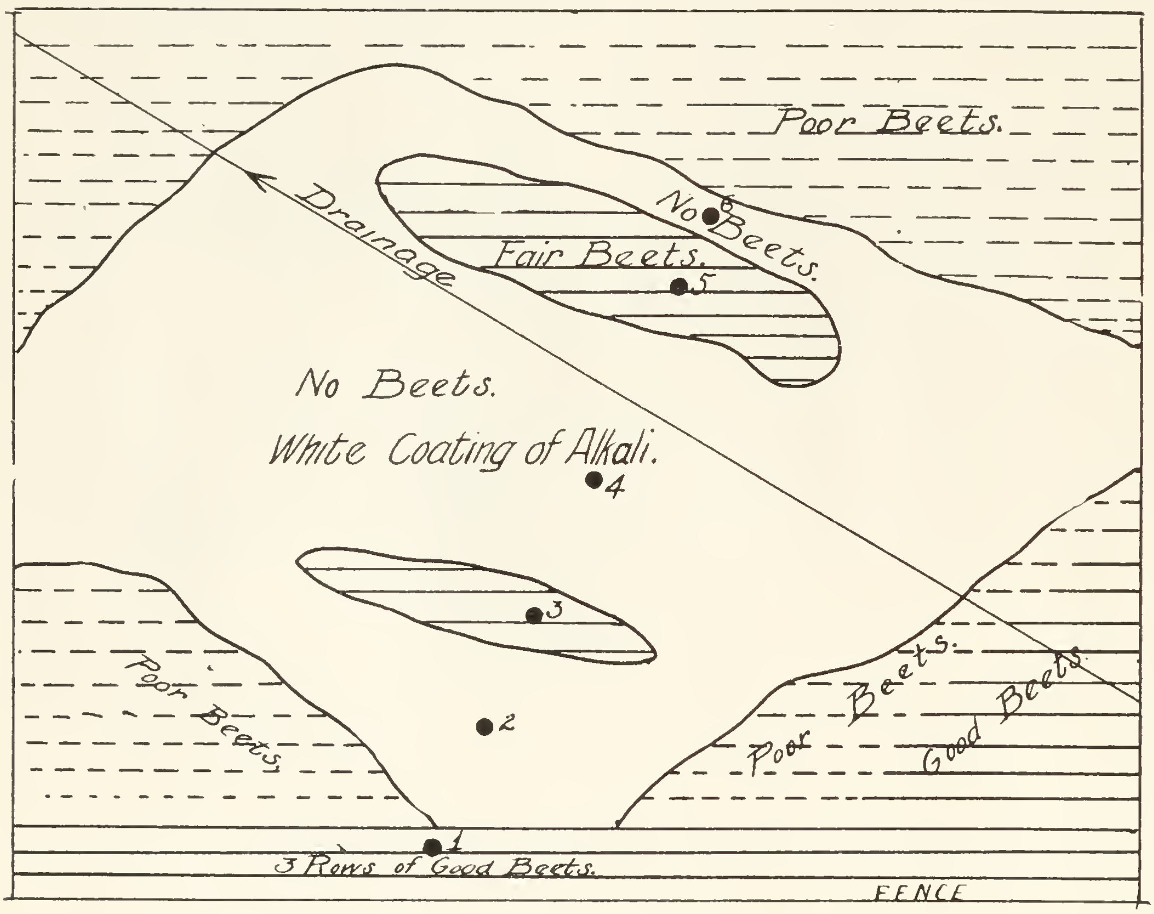

FIG. 10. Location of samples for analysis.

TABLE IV.—*Soluble Salts in Field XI, Oxnard.*

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
No. XI—1.								
First foot	.4764	trace	.0276	.5040	19,040	trace	1,120	20,160
Second foot	.0990	trace	.0186	.1176	3,960	trace	760	4,720
Average and total	.2877	trace	.0231	.3108	23,000	trace	1,880	24,880
No. XI—2.								
First foot	.1976	trace	.0552	.2528	7,920	trace	2,200	10,120
Second foot	.2152	trace	.0552	.2704	8,600	trace	2,200	10,800
Average and total	.2064	trace	.0552	.2616	16,520	trace	4,400	20,920

TABLE IV.—*Soluble Salts in Field XI, Oxnard*—Continued.

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
No. XI—3.								
First foot	.1364	trace	.0828	.2192	5,440	trace	3,320	8,760
Second foot	.1684	trace	.0644	.2328	6,720	trace	2,560	9,320
Average and total	.1524	trace	.0736	.2260	12,160	trace	5,880	18,080
No. XI—4.								
First foot	.2820	trace	.1012	.3832	11,280	trace	4,040	15,320
Second foot	.2960	trace	.4640	.7600	11,840	trace	18,560	30,400
Average and total	.2890	trace	.2820	.5710	23,120	trace	22,600	45,720
No. XI—5.								
Average and total, 2 ft.	.013	trace	.041	.054	1,040	trace	3,280	4,320
No. XI—6.								
First foot	.3108	trace	.1676	.4784	12,432	trace	6,704	19,136
Second foot	.5608	trace	.2784	.8392	22,440	trace	11,120	33,560
Average and total	.4358	trace	.2230	.6588	34,872	trace	17,824	52,696

Discussion.—Collecting the averages from the tables and developing the curve for the purpose of comparison, we have the following:

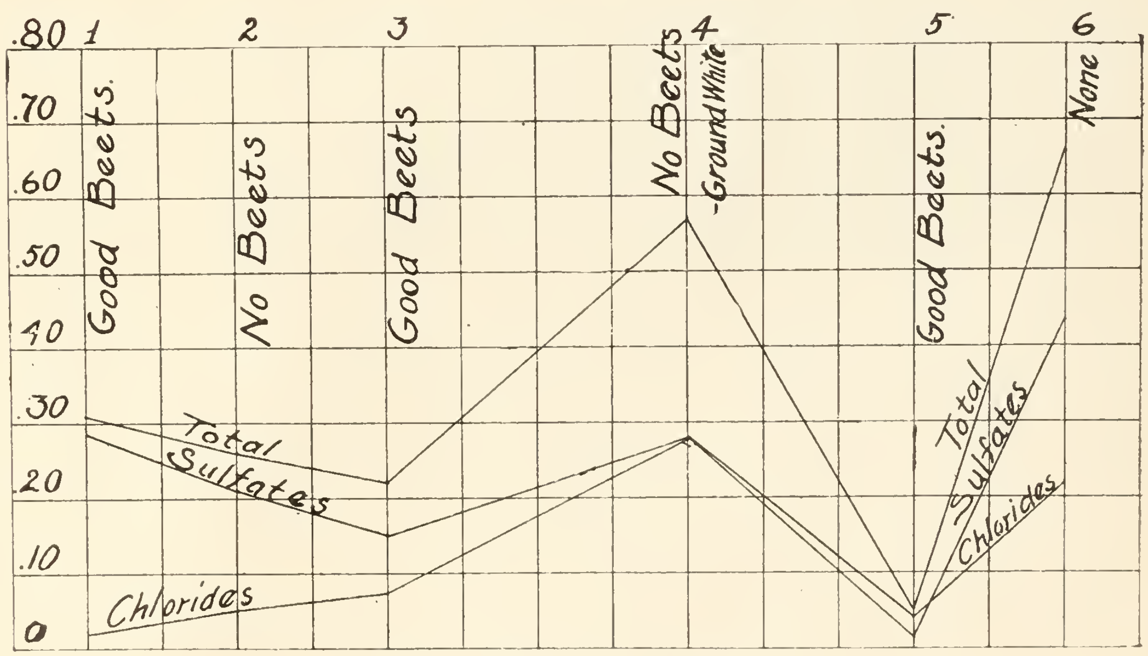

FIG. 11. Alkali curve, Field XI.

FIG. 12. Beets from stations indicated in Fig. 10.

In this location it will be noted that good beets alternate with no beets. As in the former case, there appears to be no connection which one can trace between the relation of good beets to the percentage of either total alkali or sulfate within the limits here shown, except as influenced by the chlorids. The fact that good beets occurred at station 1 with comparatively high total alkali, while at station 2 no beets were growing, is doubtless because of the increase in the chlorids as shown in the curve.

Further, the distribution of the alkali was far different at the two stations, which undoubtedly had much to do with the occurrence of beets at the one and their failure at the other station. By referring to the tabular presentation of analyses it will be observed that at station 1 *practically all the alkali was contained in the top foot*, and thus largely removed from the more delicate feeding roots of the beet, which extend very deep into the soil, as will be seen in Fig. 13.

Influence of Distribution of Salts.—At station 2, however, the concentration was essentially the same in the second foot as in the first, thus bringing the salts within the immediate reach of these delicate feeders of the plant, a fact which indicates *that not only is the total quantity of an alkali constituent a factor, but also, and perhaps even more than this, the distribution of salt in the soil*,* which also may explain why one may often find perfectly bare spots in a field known to be tainted with alkali, even though there is but little if any alkali appearing near the surface. Such an occurrence may also explain the loss of a crop in a similar field, even though the seed may have germinated well and a good stand of beets have been obtained. Whereas with a concentration of the bulk of alkali near the surface the germination of the seed would be poorer from the destruction of the germ.

*See also Report of California Experiment Station, 1894, p. 81.

FIELD IV, OXNARD.

The influence of the distribution of salts around the feeding roots of the beet also has illustration in Field IV, confirming the idea just presented, particularly as to chlorids. This was a field of 8 acres, in which the seed-bed was well prepared and the stand secured was good. The

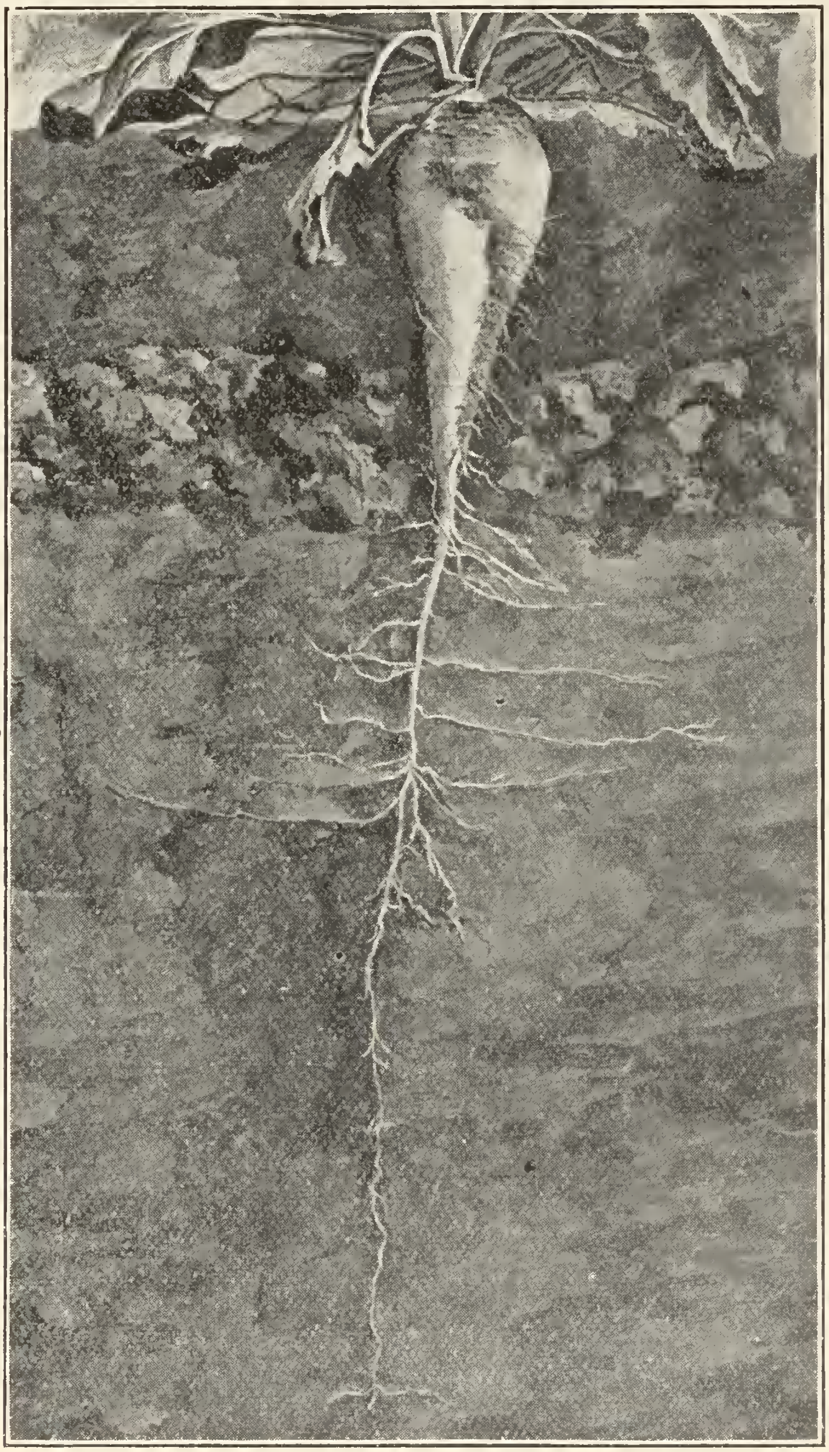

FIG. 13. Root System of Sugar Beet, showing necessity of deep preparation of soil.

field was irrigated previous to planting and had also been irrigated in shallow furrows subsequent to planting. The land north, with a slope toward this field, had been much irrigated, and there seemed to be a marked tendency for alkali to accumulate on this field. The particular thing to attract one's attention was the irregular size of the beets. On

the lower spots, where the water seemed to have stood at the time of irrigation, the beets were generally good, but on the ridges were found universally the characteristic "alkalied" beet, small, sprangly, and stubby. The general cultivation of the field had been poor, the ground being very hard as a result of flooding the land and failing to properly work the soil thereafter.

Sample 1, indicated in the table below, is a composite one from three different places where beets are good, while sample 2 is a composite one taken in the same manner from contiguous ridges on which the beets were decidedly poor.

TABLE V.—*Soluble Salts in Field IV, Oxnard.*

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
No. IV—1.								
First foot	.1980	.0084	.1120	.3184	7,920	320	4,480	12,720
Second foot	.0269	.0041	.0930	.1240	1,080	160	3,720	4,960
Third foot	.0196	.0034	.0930	.1160	780	120	3,720	4,620
Av'ge and total, 2 ft.	.1124	.0062	.1025	.2211	9,000	480	8,200	17,680
Av'ge and total, 3 ft.	.0815	.0053	.0993	.1861	9,780	600	11,920	22,300
No. IV—2.								
First foot	.2866	.0097	.2237	.5200	11,480	360	8,960	20,800
Second foot	.2627	.0097	.2516	.5240	10,520	360	10,080	20,960
Third foot	.2387	.0084	.2509	.4960	9,480	320	10,040	19,840
Av'ge and total, 2 ft.	.2746	.0097	.2376	.5219	22,000	720	19,040	41,760
Av'ge and total, 3 ft.	.2627	.0092	.2421	.5140	31,480	1,040	29,080	61,600

The sugar-content of beets from the two points was as follows:

	Average Weight.	Sugar in Juice.	Purity.
	grams.	*per cent.*	
Sample No. 1	450.0	17.0	80.2
Sample No. 2	218.0	19.0	75.9

If we consider these now in the light of previous observations as to the tolerance of beets for the several salts, there would seem little doubt as to the cause of the poor condition of the beets on the high places. On account of the more rapid evaporation from these high places the alkali has doubtless been drawn there until it has passed the tolerance of the beet.

Examining these results we find that in station 1, where the beets

were good, the chlorids are below .15 per cent, but in station 2 they exceed .20 per cent, which is the same condition which has held in each of the other cases discussed. No consideration need here be given to the sulfates, since they are much below the amount found in the former cases in which the chlorids are about the same, and in some of the former cases the sulfates even exceed the amount here. Except so far as it may have had a retarding effect upon the crop generally, it needs no consideration.

It will further be noted that in the case of station IV-2 the concentration of the alkali is even greater in the second and third foot than in the top, which alone in this case would perhaps be sufficient to prove destructive to the crop with even much smaller percentage than is here shown.

The stronger alkali upon the ridges was doubtless due to the more rapid evaporation of moisture from these spots, owing to greater surface exposure, which in turn would tend to draw the alkali salts to them—a condition usually noticeable in imperfectly leveled fields carrying large amounts of soluble salts.

A further point worthy of observation is the fact that on the low spots the alkali is concentrated in the top-foot, and is thus removed from the great mass of feeding-roots of the beet, thus interfering less with its nutrition. In the soil from the high places the alkali is more evenly distributed through the three feet, and is in each foot much above the limit named by other investigators. A further point of importance indicated is, that the tolerance of the beet for chlorids is considerably higher than observed by Dr. Hilgard, for we find fair beets here growing in an average of 4,000 pounds of chlorid per acre-foot.

That the poorer beets upon the higher places were not due to a too-limited water-content, resulting from greater exposure, is shown from the table giving the water-content of the two locations, in which it will be seen that the higher spots had considerably higher water-content, which fact was also borne out by observations in the field:

Water-content of Soil Samples from Field IV.

	Low Spots.	High Spots.
Top foot	10.38	16.58
Second foot	15.50	18.91
Third foot	20.38	18.33

This increase of moisture is in perfect keeping with the increased alkali, which always tends to render the soils more retentive of moisture. This extra amount of moisture, however, is scarcely available for the plant, and the available water for the plant may even be less, on account of the high concentration of the soil solution, due to the large quantity of alkali present. Thus we may even find the plant actually starving in the midst of plenty, on account of an inability to secure sufficient nourishment from such concentrated solutions.

Fig. 14. Field XII, showing good and poor beets.

FIELD XII, OXNARD.

This field was selected for study because of the fact that in the midst of the mother beets which were growing thereon occurred a spot of comparatively regular shape, as will be seen in Fig. 14. The general appearance of the field, and especially of the spot of "alkalied" beets, is shown in Figs. 14 and 15, in the former of which on the right, the generally stunted condition of the beets is well shown, while on the left the beets are good. In the latter the same thing is shown as to the foreground as compared with the background, the line of demarcation between good and poor beets being clearly shown in both illustrations.

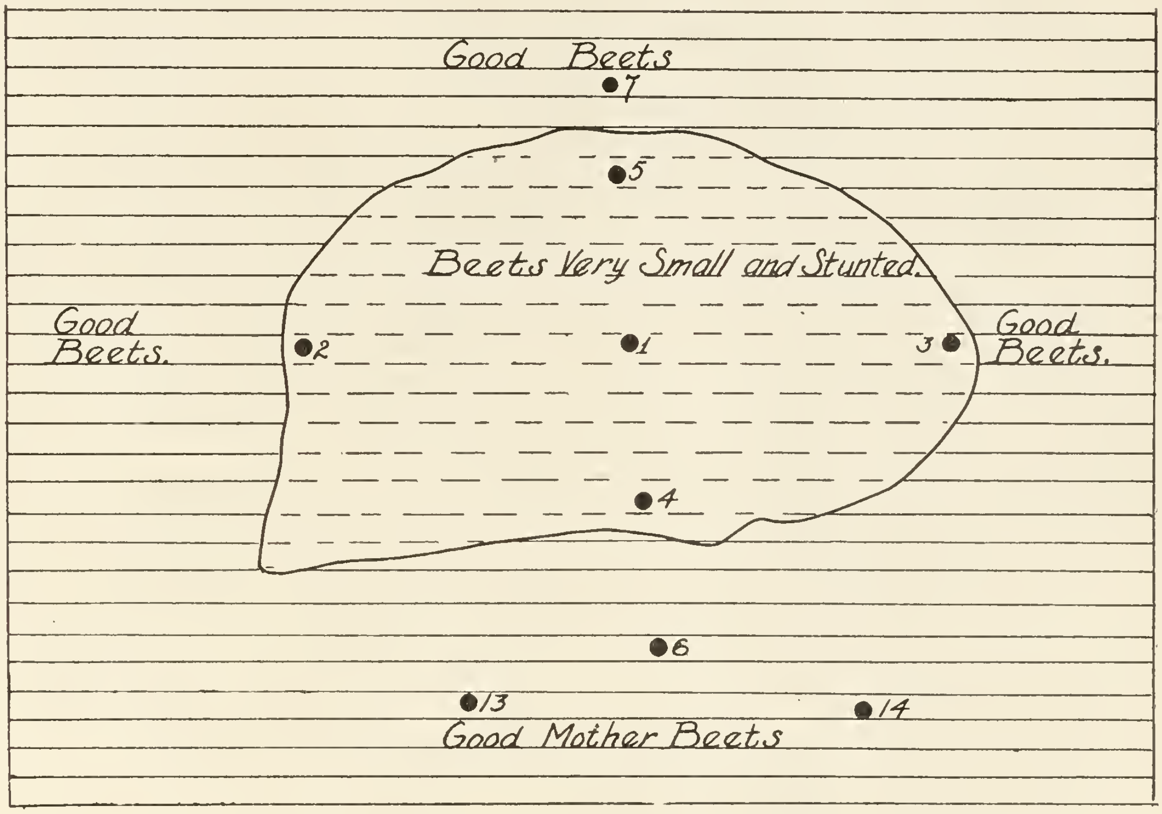

FIG. 15. Alkali spot on Field XII, showing where samples were taken.

In this field a good stand was secured, as shown in the illustrations, but after a few weeks the beets upon this spot ceased to grow. The condition of the plants is very typical of "alkalied" beets. The contrast of these beets with those taken from the other stations on the same plat is shown in Fig. 14.

On this spot we failed to find a single good beet; but entirely surrounding it were beets of both good form and size (see XII, 7, 13, and 14), although in many places could be found the tendency to "sprangle." (XII, 6.)

Alkali determinations were made upon the soils from the stations indicated in Fig. 15, with the following results:

TABLE VI.—*Soluble Salts in Field XII, Oxnard.*

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
No. XII—4.								
First foot	.3543	trace	.1949	.5492	14,160	trace	7,800	21,960
Second foot	.2810	trace	.1870	.4680	11,240	trace	7,480	18,720
Average and total	.3177	trace	.1909	.5086	25,400	trace	15,280	40,680
No. XII—6.								
First foot	.6048	.008	.1104	.7160	24,200	320	4,400	28,920
Second foot	.5220	trace	.1196	.6416	20,880		4,760	25,640
Average and total	.5634	.004	.1150	.6724	45,080	320	9,160	54,560
No. XII.								
Station 13 — Average for 2 feet	.5648	.008	.1288	.6944	45,200	640	10,320	56,160
Station 14 — Average for 2 feet	.4316	.008	.0920	.5244	16,280	640	7,360	40,560
No. XII—7.								
First foot	.9816	.008	.0736	1.0632	39,264	320	2,944	42,528
Second foot	.7402	trace	.1104	.8506	29,600	trace	4,400	34,000
Average and total	.8609	.004	.0920	.9568	68,864	320	7,344	76,528
No. XII—5.								
First foot	.1535	trace	.1949	.3484	6,140	trace	7,800	13,940
Second foot	.2670	trace	.1870	.4540	10,680	trace	7,480	18,160
Average and total	.2103	trace	.1909	.4012	16,820	trace	15,280	32,100
No. XII—1.								
First foot	.3193	trace	.2227	.5420	12,760	trace	8,920	21,680
Second foot	.3416	trace	.2320	.5736	13,680	trace	9,280	23,960
Average and total	.3304	trace	.2274	.5578	26,440	trace	18,200	45,640

Discussion.—This spot is an especially good illustration of the limits of alkali tolerance by the sugar beet on account of the clear line of demarcation between good and poor beets under otherwise uniform conditions. That the beet will tolerate a large total alkali, provided the preponderance of the salts present is in the form of sulfates, is clearly shown in the curves shown in Fig. 16, the total at station 7 being nearly 1 per cent, 0.86 of which is composed of sulfates. Under these conditions the field was producing beets of at least fair size, of good sugar-content, and of good form. These beets continued as far as station 5, when the condition suddenly changed, and small, stunted, scraggly beets, characteristic of this and other alkali spots of the same locality, occurred, and

this notwithstanding the total alkali and sulfates have decreased to .40 per cent and .21 per cent, respectively. Looking for the cause of this stunted condition we note that there has been a rise in chlorid content to approximately .20 per cent at the spot where the beets become markedly poor. Further, we note that the condition remains the same so long as the chlorid content of the soil remains above .20 per cent,

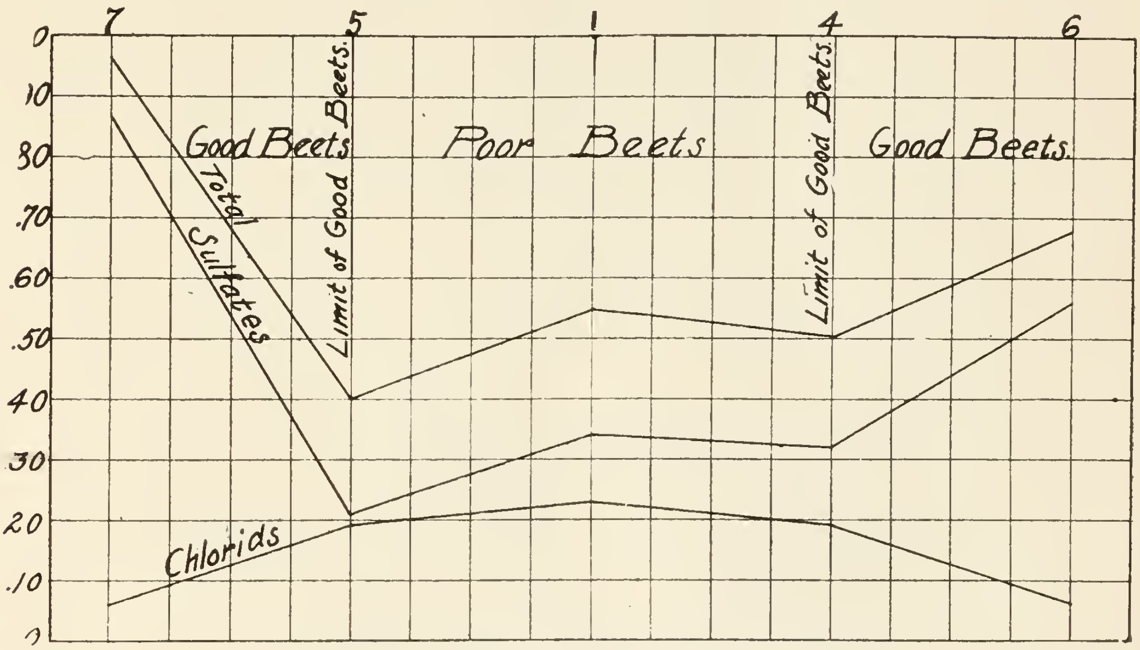

FIG. 16. Alkali curve for Field XII.

FIG. 17. Beets from Field XII.

but upon falling below this point at station 4 the beets at once improve and become of normal form, size, etc. (witness Fig. 17, XII, 6, 13, and 14), notwithstanding the sulfates have increased from .32 per cent at 4 to .56 per cent at 6.

From this examination it would appear that on a sandy loam soil, under proper conditions of culture, we may expect beets to thrive when the total alkali reaches as high as 1 per cent, *provided the chlorids do*

not exceed .20 per cent. Had the sulfates remained as high as .85 per cent, and the chlorids increased as shown, it is probable that the area of good beets would have been lessened, and the limit of chlorids been somewhere from .15 to .20 per cent. The effect of the sulfates appears to be very mild, however, as at station 5 with sulfates as low as .21 per cent the chlorid limit is .19 per cent, and it is essentially the same at station 4, where the sulfates have risen to .32 per cent, or more than doubled. It would be difficult to find a case in which the effect of the chlorids is more clearly shown than here, the indication being that in the absence of carbonates, chlorids are the governing factor and must be below .20 per cent if we would expect success in the production of beets.

FIELDS I AND II, OXNARD.

The attention of the writer was called to two different fields in the same general region. It was said by those familiar with the conditions covering several years, that on No. I it was impossible to bring a crop of beets to maturity, even though under very favorable conditions a stand might be secured. Barley had also failed upon this soil, although the seed had germinated and the plants lived for a short time. On Field No. II there had been some difficulty in securing a stand, but when a stand was once secured the beets grew very well. A comparison of the two soils does not reveal any great difference in physical characteristics, although No. I may carry a little more clay than No. II, but not enough to make it evident to the eye. A comparison of the soluble salts, however, shows a very strong contrast.

TABLE VI.—*Fields Nos. I and II, Oxnard.*

Depth—2 ft.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
Field No. I	.3004	trace	.3340	.6344	24,000	trace	26,720	50,720
Field No. II	.1456	none	.1020	.2476	11,680	none	8,160	19,840

While it does not appear as to why there should be difficulty in securing a reasonable stand upon this field, if we accept the evidence previously presented as to the apparent limits of chlorids, we certainly find a satisfactory answer as to why the crop does not succeed upon Field No. I, on which the chlorids are a third higher than the limiting number on the locations already discussed. Further, the results add still stronger evidence for the contention that it is unsafe to attempt to grow

sugar beets upon land carrying .20 per cent or over of common salt, and on soils carrying even .15 per cent there will be great uncertainty of a crop, unless other conditions are very perfect.

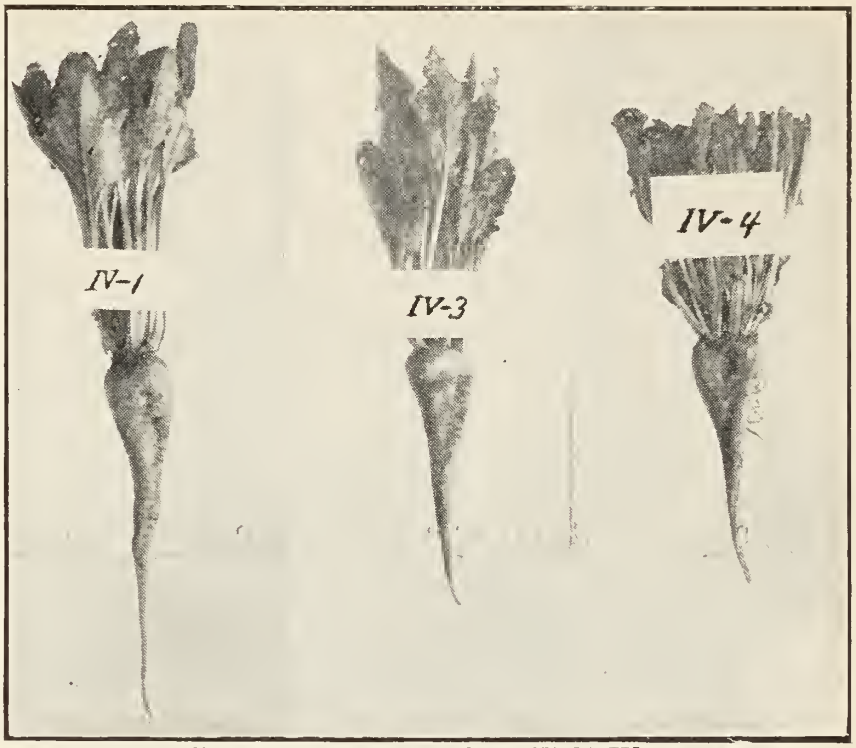

Fig. 18. Good beets from Field IV.

The fact that these results were obtained on these soils under the conditions existing this year is not necessarily conclusive that the same soils under somewhat different conditions of treatment or seasonal moisture might not produce good beets over their entire area; but it is suggestive that a knowledge of the conditions previous to planting upon a soil might save considerable expense to both the farmer and the company. With the rapid methods of analysis which can now be employed in making approximate determinations of the alkali in soils over considerable areas, there would appear no reason for continuing to plant beets upon soils entirely unsuited, or even precarious for the crop. It is usually true that there are but comparatively few fields so affected with alkali as to make them uncertain for crops from this standpoint, and these doubtful fields could easily be investigated from the standpoint of their soluble salts and planting done in accordance with the results obtained by such examination. It

Fig. 19. Good beets from Field X.

suggests a closer attention to the field of agricultural chemistry by the sugar companies operating in the arid regions especially. The writer believes that far too great attention is paid to the factory side of the sugar industry as compared with the agricultural, and that the highest results can never be attained, especially in the arid region, until rational attention be given to agricultural chemistry in connection with the field operations.

Good Beets Frequently Grow in Strong Alkali Soil.—One who has had experience in beet fields affected with alkali is soon impressed with the fact that there seems to be individual beets much more alkali resistant than those immediately surrounding. Here and there one finds individual beets, in the midst of other beets badly "alkalied," making a strong and healthy growth and carrying a good per cent of sugar and purity, and maintaining a good form of the beet, viz., a long, straight and symmetrical root. That such a form is unusual for beets grown under these conditions, is clearly shown in the illustrations of beets taken as typical of the alkalied fields here studied.

Below is shown the alkali-content, to a depth of two feet, of the exact spot in which these beets were growing, and also the sugar-content of the beet in each case.

TABLE VII.

Depth—2 ft.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
IV—1	.1536	trace	.0920	.2456	12,320	trace	7,360	19,680
IV—3	.2986	.0097	.1277	.4360	23,840	800	10,240	34,880
IV—4	.0920	.0042	.1278	.2240	7,360	320	10,240	17,920

Other illustrations of the same thing are shown in the following table, the beets from which are shown in Fig. 19:

TABLE VIII.

Depth.	Percentage in Soil.				Pounds per Acre.			
	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali	Sulfates	Carbonates (as Sodium Carbonate)	Chlorids (as Sodium Chlorid)	Total Alkali
X—5.								
First foot	.0688	.0025	.0326	.1039	2,760	120	1,320	4,200
Second foot	.0511	.0050	.1118	.1679	2,040	200	4,480	6,720
Average and total	.0600	.0037	.0722	.1359	4,800	320	5,800	10,920

The occurrence of so typical beets growing under such adverse conditions, and the development of the beet to such a high state by the process of continued selection, suggests the possibility of producing by the same methods a type of beet which shall be much more alkali resistant than those now being grown in this country, the seed of which has been produced under the very best of conditions in alkali-free soil in Europe. Such a beet would meet a need which is now very apparent in the irrigated regions of America, and would be a decided factor in aiding to place the agricultural side of the industry on a firmer footing

Fig. 20. Selected beets from strong alkali soils.

than is now the case. The most difficult thing now appears to be to induce the farmer to so conduct his agricultural operations, especially as to the selection and preparation of the soil, as to secure such a yield per acre as to make the industry continually inviting, and in those regions where alkali is prevalent in the soil it is one of the greatest obstacles to overcome. Further, the development of a more alkali-resistant beet would make it possible to considerably extend the area now available, and bring under cultivation to a generally profitable yield a large amount of land for which it is now difficult to find satisfactory crops.

Note.—It is desired hereby to express thanks to the American Beet Sugar Company, who assisted in this work by allowing the use of their laboratory; to Mr. C. L. Colvin, chemist of the above-named company, for courtesies received; and also to Mr. Frank D. Merrill, who assisted in certain of the analytical work.

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160. The Hop Aphis.
161. Tuberculosis in Fowls.
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165. Asparagus and Asparagus Rust in California.
166. Spraying for Scale Insects.
167. Manufacture of Dry Wines in Hot Countries.
168. Observations on Some Vine Diseases.

CIRCULARS.

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4. Anthrax.
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9. Asparagus Rust.
No. 10. Reading Course in Economic Entomology.
11. Fumigation Practice.
12. Silk Culture.
13. The Culture of the Sugar Beet.
14. Practical Suggestions for Codling-Moth Control in the Pajaro Valley.

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